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A PLAN FOR APPLYING PERFORMANCE-ORIENTED
CAI IN NAVAL TECHNICAL TRAINING

Joseph W. Rigney

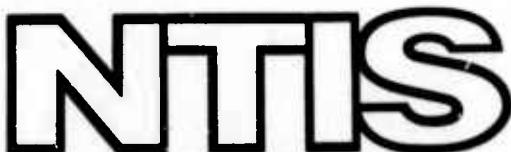
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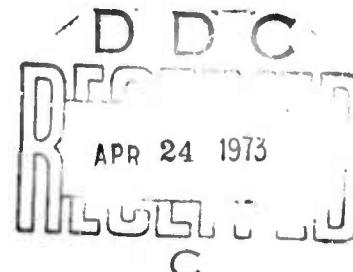


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A PLAN FOR APPLYING PERFORMANCE-ORIENTED
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Quarterly Technical Report
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Joseph W. Rigney

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One of the objectives of this project is to develop a plan for extending performance-structure oriented (PSO) CAI that was successfully applied to teaching basic skills to Radar Intercept Observers, to a set of similar jobs in Naval operations. (U)

In this technical report, the approach that will be taken to the development of this plan is outlined. This will involve expansion of the steps that were followed in the production of the RIO trainer, to include the additional dimension of different jobs in the set selected for consideration. Thus, comparative analyses across training requirements for these jobs will be made, to identify commonalities, with respect to knowledge and skill requirements, instructional operations in the Instruct and Practice modes, task mixtures in the top-level performance sequence, and response recording and analysis, and adaptive control requirements. (U)

The theory of how human performance is organized is briefly discussed, since this determines the organization and instructional strategy used in PSO CAI, these features of PSO CAI are then described. (U)

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I. INTRODUCTION

In earlier work (Rigney, et al., 1973), an individual skills trainer for Radar Intercept Observers, using performance-oriented CAI, was developed and was evaluated in the RIO "basics" school. This approach to teaching basic skills is potentially applicable in a variety of contexts in Naval training. This extension would be facilitated by a systematic examination of the systems design kinds of issues in matching instructional resources, particularly instructional operators, to the structure of tasks to be learned and to the characteristics of student populations. This report will describe the approach that is being formulated for the systematic consideration of these issues. Since there have been many general feasibility studies of CAI, a number of detailed RFP's that attempt to specify requirements for instructional systems, and some prior research on the design of these systems (e.g., Carpenter, et al., 1972), it is necessary to describe the specific concerns of this current approach. First, it deals with performance-structure oriented CAI, in distinction to what Carbonnel (1971) called ad-hoc frame-oriented CAI, or computer-administered programmed instruction. Second, it is confined to a relatively small group of Navy jobs in aviation operations which hopefully will be a manageable sample for the analytical resources available. Third, it is primarily concerned with the matching of instructional operators with types of content found in this sample of jobs.

Instructional operators are ways of presenting stimulus material, and operations that can be required of the student, that will facilitate

learning and improve retention. In the present context, they consist of operations that can be implemented with a graphics display, light pen, suitable auxiliary displays and response entry devices, and generative logic for creating and managing the interaction with the student. An example of an instructional operator is the simultaneous display of true and relative motion between bogey and fighter during an intercept problem, to allow the student to relate the motion in the relative display to the motion in the true display. Another example of an instructional operator is logic that automatically repeats a problem in a "free trial" mode if a student fails to achieve a minimum level on a practice problem.

The application of instructional operators in relation to what is to be taught and who is to learn it is the key to increasing the effectiveness of CAI. According to this conception, instructional operators would be used during the instruct and practice stages in the instruct-practice-test sequence that is basic to all instruction, and would be managed by control operators embedded in some method for optimizing individualized instruction.

Ideally, task and content analysis, and allocation of instructional operators to resulting categories, would be done automatically by a computer program. Clearly, the present state of instructional technology does not provide this luxury. To do this, there is a need for a way of representing the structures and operations in some common formalism that would be suitable for translation into program logic. Graph theory immediately comes to mind as a possibility. There are in the literature examples of its use, in one or another forms, to represent and to analyze a variety of structures, e.g.; group communications patterns, electronic circuits, and the syntactic aspects of language.

One of the objectives of this research is to investigate the possibilities for using graph theory to represent and to manipulate the kinds of structures encountered in planning CAI applications. This investigation will be pushed only as far as necessary to identify the requirements and to make a decision regarding the potential payoffs. If it appears that it would be fruitful to use graph theory to assist in developing the application model for the sample of N_z al jobs, this will be done. Otherwise, more conventional methods will be used.

Other important issues for planning the application of CAI to a spectrum of jobs are the optimization of individualized instruction, which includes instructional sequencing and control; and cost-effectiveness. Atkinson and Paulson (1972) have discussed the requirements for optimizing individualized instruction, have described several methods they have used, and have made it clear that estimating cost-effectiveness depends on the consumer's value judgments of the worth of alternative objectives. These other issues are considerations for any CAI application, and since they are treated so ably by Atkinson and others, they will not be a major emphasis of this work. The individual trainer developed for the RIO already uses simple adaptive logic. This will be refined as part of the further development of this trainer. Some crude cost comparisons can be made with the other existing device for RIO basic procedural training. Keep in mind that this existing device is oriented more toward radar operator training and that the BTL trainer is oriented more toward procedural training and thus the sets of procedures each teaches overlap but are not identical. This device costs approximately 10 times as much, requires an instructor to operate it, does not record and analyze student responses, is very expensive to modify, breaks down frequently, and provides less "on-line"

practice time to each student. Since it does not record and analyze student responses, there is no basis for optimizing learning, nor any basis for estimating its effectiveness.

II. PERFORMANCE-ORIENTED CAI

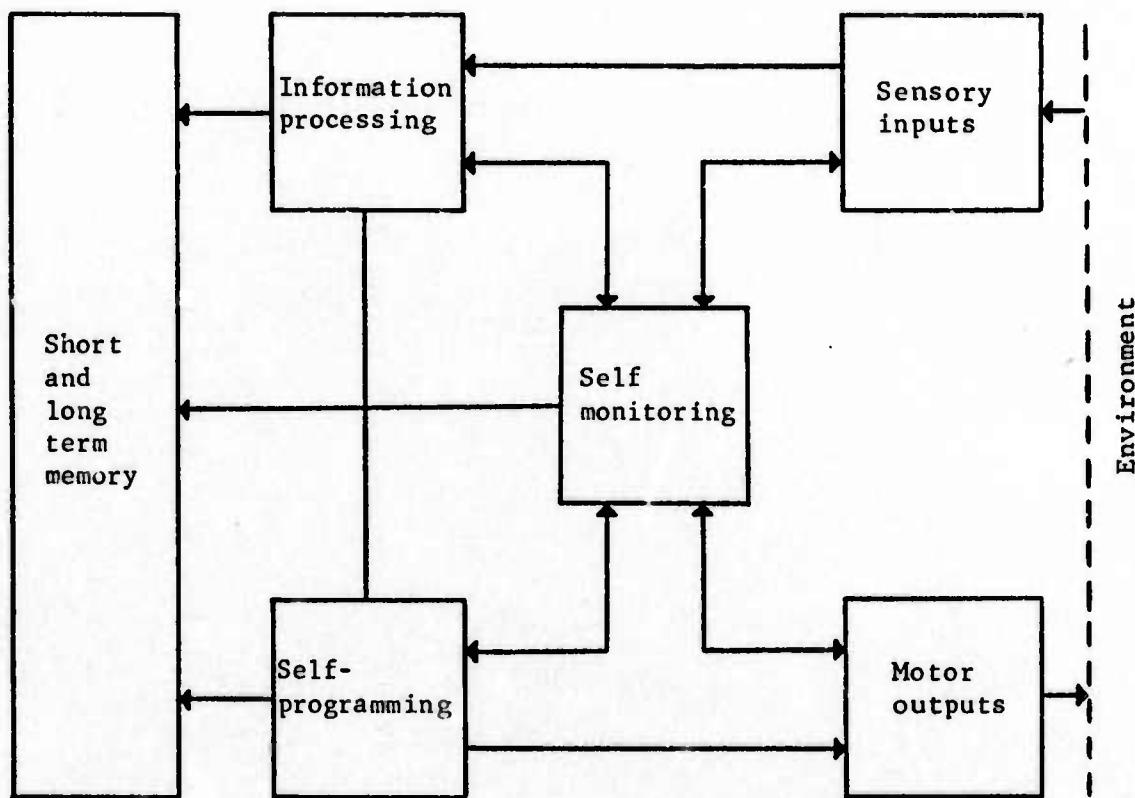
Properly controlled practice results in increased proficiency. This may be the fundamental law of training. Its power is demonstrated every day in literally thousands of different settings. Great fluency in performance is produced only by large amounts of properly controlled practice. This may be the second law of training. Of course, the key phrase in these statements is "properly controlled." Repetition provides the context in which mediating processes can occur. These must be directed by the manipulation of conditions external to the learner, e.g., by instructional operators. Improperly controlled practice at the least may be inefficient. At the worst it may be disastrous. This also is demonstrated every day.

Despite the universality of these laws, it is not always easy or even feasible in some training environments to provide opportunities for properly controlled practice to each student in amounts sufficient to bring him up to a desirable level of fluency. PSO CAI was developed to provide individualized, properly-controlled practice as automatically as possible. That is, it should bring the individual student up to some desired level of proficiency without requiring the constant attention of an instructor during the practice period, and without requiring an operator in addition to the student during the practice period.

In this section, we will discuss the assumptions about the organization of human performance that are the "theoretical" basis for PSO CAI, and describe procedures used in its development, to provide a background for the following sections.

The Organization of Performance

The view of performance as a highly organized serial mixture of subgoals and associated action clusters, sustained by groups of mediating processes, has been described elsewhere (e.g., DeGreene, 1970). This is essentially an information-processing conception derived from the literature of information-processing (Reitman, 1965) cognitive (Neisser, 1967), and cybernetic (Pask, 1970) psychology in general, and from recent literature on mediating processes in learning and memory (e.g., Tulving and Donaldson, 1972; Carroll and Freedle, 1972; Sheehan, 1972; Glaser, 1971). Some of the major kinds of mediating processes that are required to sustain performance at its highest level are at least suggested in the following figure:



The organization of serial-action performance

We suggest that many mediating processes in each box in the figure are learned, and that this learning consists essentially of elaboration of complex processes from some sort of primitive substrate of biologically determined processes, perhaps common to all mammalian forms of life. According to this view of the organization of performance, it can occur at least at two, and probably at several levels of serial integration. At the highest level, the performer generates the series of activities involved by a self-program that is flexible enough to meet the contingencies of the immediate situation. Perhaps this self-program is a skeleton routine that is filled out with one of several available subroutines at each point in the performance, somewhat in advance of the activities generated by that subroutine. The requirement for this extemporaneous self-programming would depend upon the unpredictable variability in the performance requirements. When he can stay at this highest level, the performer is essentially through with training. The fact that he can perform autonomously and meet criteria for proficiency indicates that.

Before this time, the performer is dependent on external instruction. He may be able to sustain his performance at the top level only some of the time. In between, he must concern himself with learning some needed subskill he did not know, or with learning some needed information he did not have, or with learning control processes necessary to string subskills together into the correct serial mixture, to monitor his performance for errors and for correct timing, etc.

There is little doubt that this kind of learning is partially dependent upon self-organizing processes. We do not know, except by indirect and usually ambiguous observations, much about the exact nature of mediating processes. Those that we do know something about as a consequence of

laboratory research possibly are only "surface" manifestations of even more obscure processes which tend to be self-organizing. On the other hand, as both Bruner (1966) and Pask (1970) have pointed out, in the early stages of learning the student is not in a position to instruct himself. He has entered into a kind of contract with the instructor, human or machine, which includes the idea that the instructor will be responsible for providing effective, high quality instruction, until the student has learned enough to become more self-directed.

An Integrated Approach to Teaching Performance with CAI

If the above views of the nature of performance are correct, any method for teaching students how to perform by giving them properly controlled practice must be sensitive to structures; to the serial patterns of performance, to the levels of integration, to task structures, and to, where these are involved, device structures.

One way to do this is to simulate essential characteristics of the performance situation, providing a series of graded practice problems, procedures for moving up and down across levels of organization, adaptive control sensitive to individual differences, instructional operators matched to the different learning requirements, and sufficiently detailed response analysis to guide adaptive control and to provide a description of how well the system is working. Of course, job or task simulators have been around for a long time, but they have, in most cases, been woefully incomplete. The major emphasis in their design usually has been on fidelity of simulation, while adaptive control, instructional operators, movement across levels of performance organization, and detailed response

recording and analysis usually have been altogether absent. Simulation alone does not provide adequate control over practice.

Some advantages of this approach are:

1. The performance is the criterion test. Students are "taking the test" while practicing.
2. Students can iterate back and forth between the top level and lower levels, receiving extra drill on subskills in which they are weak and returning to the top level to try again to perform at that level.
3. No time is wasted in presenting material the student already knows. If he can do it, he is automatically transitioned by the program logic to more difficult material.
4. The student learns self-monitoring and self-programming processes needed in the context of the actual performance, as well as the information-processing skills that usually are the sole concern of instruction.

Steps in the Development of Performance-Oriented CAI

The procedures followed for developing this type of CAI for one training situation can be simpler than if it is to be extended to a set of situations. Then it is worthwhile considering questions of what aspects of the development can be generalized and how much. Under certain circumstances, generative programming can be used to reduce the labor of preparing instructional sequences. Commonalities can be sought among mediating skills, content, and instructional operators.

The general steps that were followed for the development of the RIO program are:

1. Achieve a thorough understanding of the serial composition of the performance to be taught.
2. Analyze each different task in the serial string to a depth sufficient to reach the probable lower bound of the student population's entering skills and knowledge.
3. Identify elements in the task hierarchy that require special instructional operators and develop specifications for these.
4. Produce an instructional flowchart for the interactions between student and program. This is the instrument for communicating between the instructional technologist and the computer programmer.
5. Produce program flowcharts and write the computer program.
6. Concurrently, produce the data base for the program.

Steps 4 and 5 typically will require several iterations before the instructional flowchart can be translated into program flowcharts, since the two are quite different. The programmer has to understand what is wanted in the student-program interaction and then has to produce what amounts to entirely different flowcharts.

Step 2 deals with an important issue, what might be called the "instructional bandwidth" of a CAI system. What assumptions are made about the levels of entering skills possessed by the student population? How wide a range of skills must the system be designed to teach? PSO CAI moves a student to a lower level of performance, to practice some sub-skill, for some relatively short time, then the student tries to perform at the higher level again. Clearly, in this drill and practice mode, it is not the purpose of the drill levels to give lengthy courses in

fundamental skills. There must be some cutoff point. Since PSO CAI is designed to be used in courses in which other training methods impart "theory," the student population is likely to have been selected already. These selection criteria usually would be suitable for the entering bandwidth of the CAI system.

These general steps will be followed in the development of a model for extending this type of CAI to a range of different training requirements. An initial classification scheme will be used to expand each step by adding the dimension of different jobs, so that a two-dimensional array, rather than a single vector of elements will result from the work.

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